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(54) Cross-section of non-circular filaments

(57) The cross-section of a filamentary object, especially an object having a non-circular cross-section, is measured by means of a focussed beam of light 11 which is subjected to a parallel sideways displacement motion within a measuring field 15 in which the object 22 to be measured is positioned. After passage across the field the beam is detected in a detector 17 except when obscured by the object 22 so that the period of obscuration is a measure of the cross-section of object 22 in the direction of displacement of the beam. The displacement motion is carried out from a plurality of different orientations relative to object 22. This may be achieved by securing the optical system on a holder 3 which is rotatably mounted on a part-circular guide 2. Alternatively a plurality of optical systems may be provided each fixed at different orientations relative to the object.

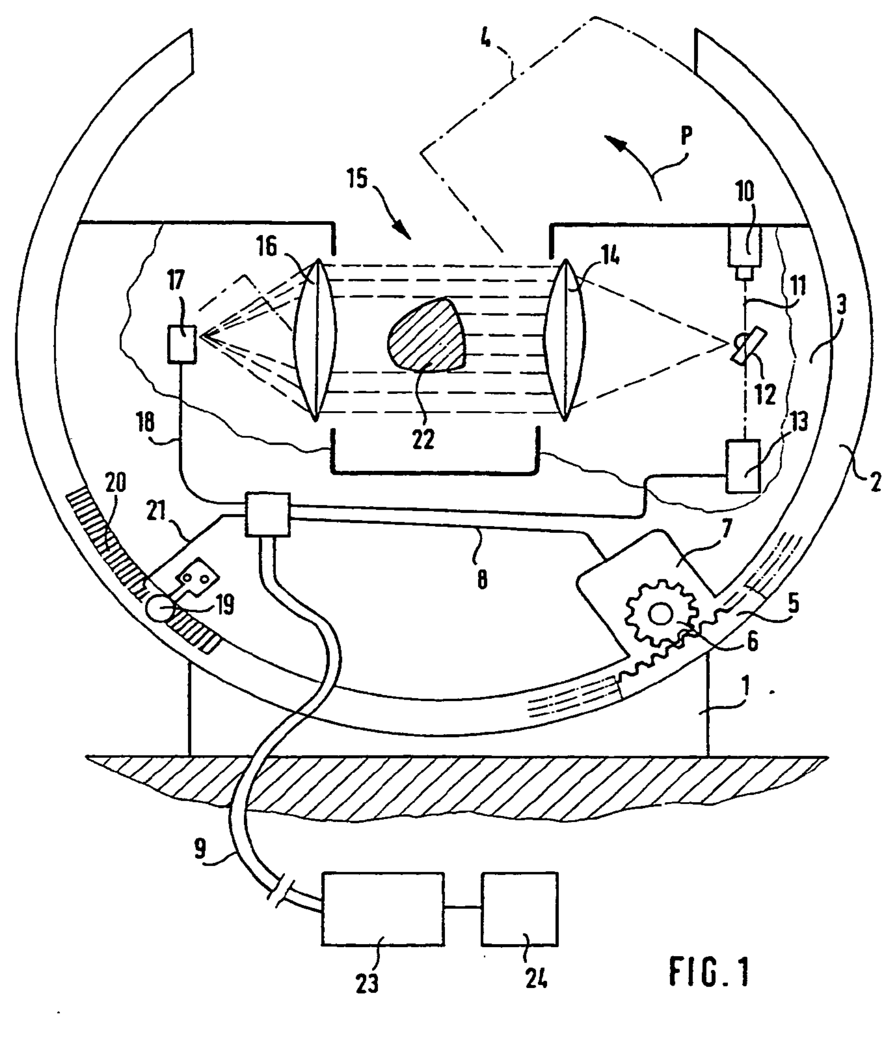

FIG. 1

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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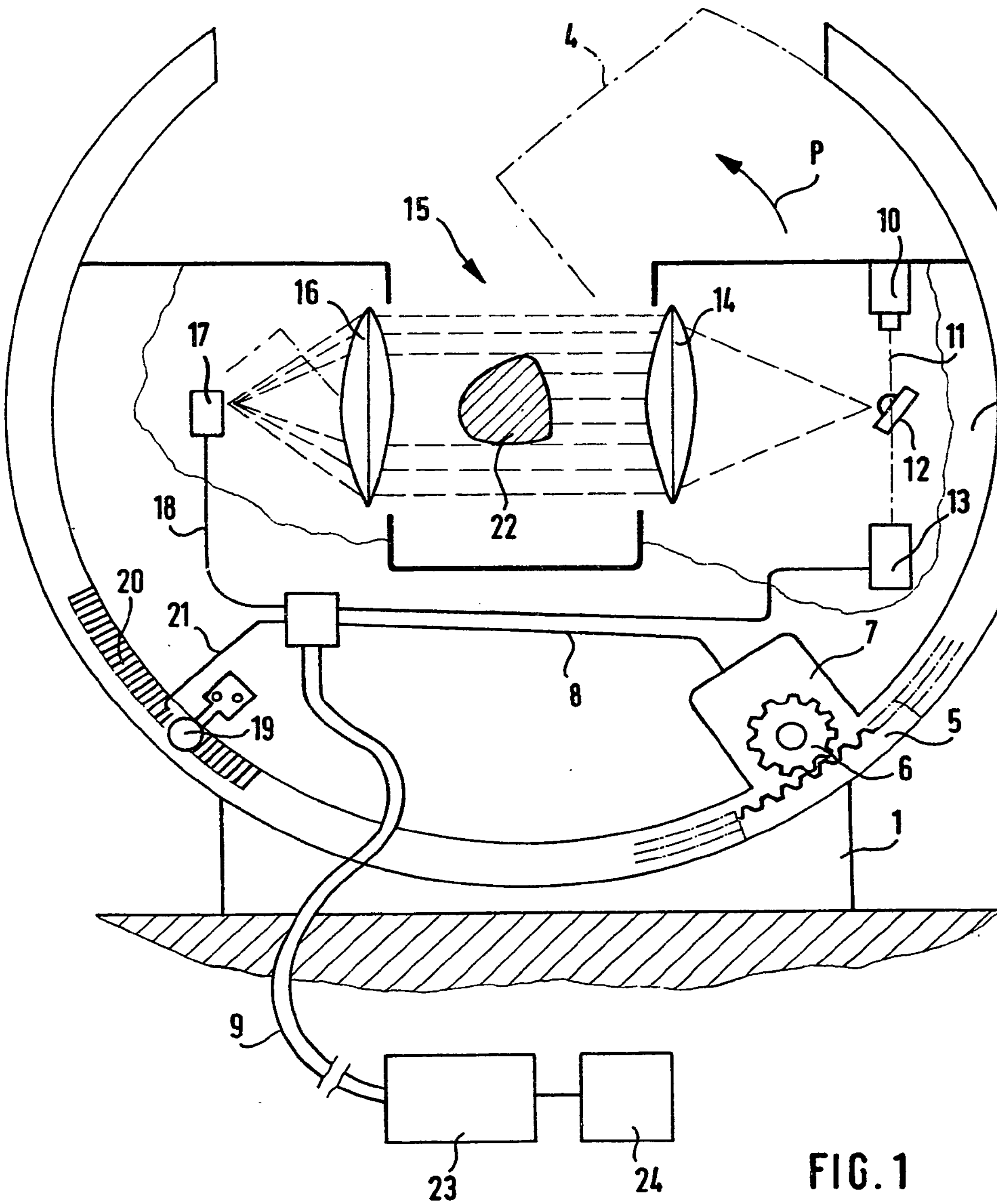
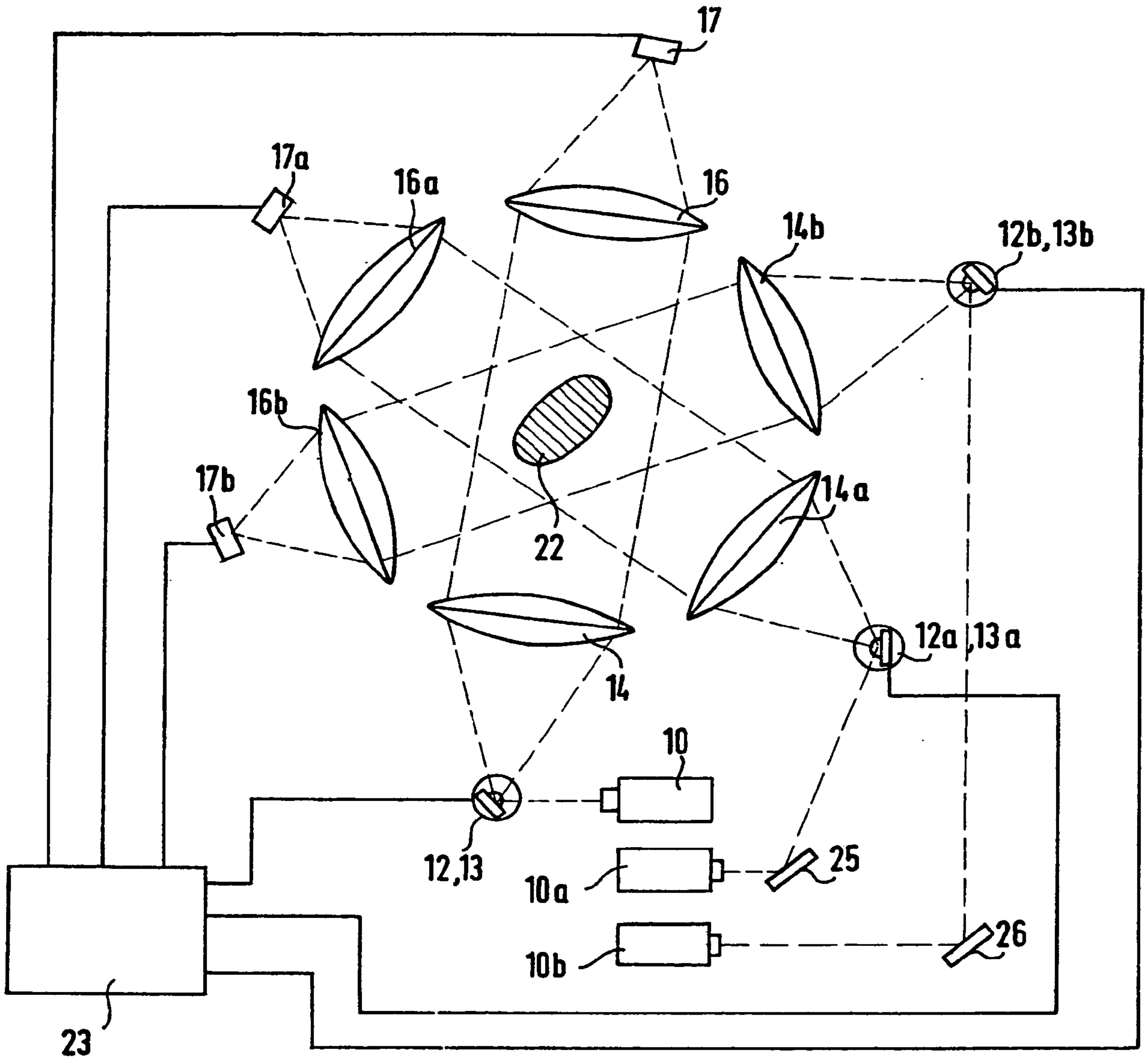


FIG. 1



17
17a
16a
16
14b
12b,13b
16b
17b
22
14a
12a,13a
14
10
12,13
10a
25
10b
26
23

FIG. 2

SPECIFICATION

Methods and apparatus for measuring the cross-section of filamentary objects

This invention relates to methods and apparatus for measuring the cross-section of filamentary objects and particularly objects on non-circular cross-section.

In one known method a focussed light beam is rotated in a scanning plane and the rotational movement of the light beam is converted within a measuring field into a parallel sideways displacement motion. After traversing the measuring field the light beam is deflected onto a detector. During the parallel displacement motion the light beam is obscured for a defined time by an object which is present in the measuring field. This time is a function of the size of the cross-section in the direction of displacement and can be measured by the output signal from the detector.

Measuring techniques of this type can be inferred from US Patent 3765774, or from German Patent 2849252. If the intention is to use this known technique for making measurement of non-circular cross-sections, it is necessary to rotate the object which is to be measured in the measuring field to enable its maximum and minimum diameters to be determined.

In certain applications, however, it is impossible to rotate the object to be measured, for instance in the case of the manufacture of filamentary products in continuous lengths which it is not desired to divide into sections. Examples of such products are rolled profiles, extruded profiles, drawn wires, and similar products.

The invention is thus intended to solve the problem of being able to measure non-circular cross-sections of filamentary objects in a precise manner, even when it is impossible to rotate these objects about their longitudinal axes.

This problem is solved according to the invention by means of a method whereby a scanning process is carried out in several different directions, the orientation of the cross-section of the object being constant with reference to its surroundings.

According to one preferred embodiment the above-mentioned scanning process is carried out by apparatus in which a rotating mirror and a collimator, the latter configured as a lens or concave mirror, are provided on one side of a measuring field, and serve to generate a parallel sideways displacement motion of the beam within the measuring field, while a fucussing device is provided on the far side of the measuring field which serves to deflect the light beam onto a detector, all these devices being installed on a rotating holder which is mounted in a manner permitting rotation around the object to be inspected.

Apparatus of the above type enables the diameter of an object possessing a non-circular cross-section to be determined, in any desired number of directions, or more precisely, enables the size of its shadow to be determined in this way. It is expedient if the position of the rotating holder relative to a datum mark on the equipment can be determined by means of an angle-sensor which is installed beween the rotating holder and a guide or mounting so that particular angular-position values are assigned to individual cross-sectional measurement values.

According to another embodiment of apparatus for carrying out the method of the present invention a plurality of systems are located at fixed positions relative to the measuring field and orientated in different directions relative to the cross-section of the object to be inspected, each of these systems possessing a rotating mirror for generating the swinging movement of the light beam and a collimator for generating the parallel sideways motion of the beam and a focussing device for deflecting the light beam onto the detector after passage across the measuring field.

In the case of an arrangement of the above type the number of directions in which the diameter, or the size of the shadow, can be determined is limited, but there is the advantage that all the measurement results are available for evaluation at the same time, since there is no need to wait for mechanical rotation of a holder.

In order to understand the invention illustrative embodiments are described in more detail by reference to the drawings in which:

Figure 1 is a diagrammatic representation of apparatus for measuring non-circular cross-sections of filamentary objects, this apparatus possessing an optical scanning system which can be rotated in a plane, and

Figure 2 shows another embodiment of apparatus for measuring non-circular cross-sections, this apparatus possessing a plurality of fixed optical systems.

The apparatus shown in Figure 1 incorporates a guide track 2 which is secured to a base-member 1 of the apparatus. Guide track 2 extends over an angle of approximately 270° and an approximately C-shaped or horshoe-shaped rotatable holder 3 is mounted in guide track 2 in a manner permitting swinging or rotation, as depicted in Figure 1 by the arrow P. The limiting position of the rotating holder 3 is indicated by the dashed line 4.

An internally toothed ring 5 extends along the guide track 2, the drive pinion 6 of a drive motor 7 meshing with these teeth. Drive motor 7 is secured to the rotating holder 3 and is supplied with electrical power via a line 8. A flexible cable 9 is connected to line 8 and leads from the rotating holder 3 to switching devices at the side of base-member 1 in a manner such that the rotating holder 3 can be moved by the drive motor into whichever position is desired.

A source for a focussed light beam, for example a laser 10, is mounted on that limb of the rotating holder 3 which in Figure 1 is located on the right side. The beam 11 from this laser is incident on a rotating mirror 12 which is caused to rotate by means of a motor 13. Rotating mirror 12 and motor 13 are secured, as is the laser 10, to the

rotating holder 3. The light beam, after being reflected and rotated by the rotating mirror 12, strikes a collimating lens 14 which converts the rotational movement of the light beam into a parallel sideways displacement motion such that, when the rotating mirror 12 is caused to rotate, the scanning light beam sweeps in a parallel sideways displacement motion across a measuring field 15 which is located between the limbs of the rotating holder 3.

On that side of the measuring field 15 remote from the collimating lens 14 scanning light beam strikes a convergent lens 16 which is mounted on that limb of the rotating holder 3 which is represented to the left in Figure 1. This lens focusses the scanning light beam onto a detector 17 which is likewise located on that limb of rotating holder 3. The output signals from the detector are supplied to evaluating units via a line 18 and via the flexible cable 9.

Lastly, a sensing head 19 is located on the rotating holder, this sensing head sensing optical raster marks 20 on the guide track 2 and supplying output signals, via a line 21 and the flexible cable 9, to evaluate units at the side of the base-member 1.

The laser 10, the rotating mirror 12 and its motor 13, the lenses 14 and 16 and the detector 17 function in conjunction with one another. An object 22 is located in the measuring field 15 and obscures the scanning light beam for a defined time during its sideways displacement motion. This time it is function of the size of the cross-section in the scanning direction and can be measured by the output signal from the detector 17. The speed or rotation of motor 13 and the variation of the signals from the detector 17 with respect to time are used to calculate the size of the cross-section of the object 22 in the scanning direction, this calculation being performed in an evaluating unit 23.The result is indicated on a display unit 24, or is recorded. At the same time an angle value is displayed or recorded. This angle value is calculated from the output signals from a sensing head 19 which indicates the position occupied by the rotating holder 3 relative to base-member 1 at the same time at which the object 22 was scanned and at which a corresponding diameter value was recorded. In this way the cross-section of the object 22 can be inspected by reference to the size of the shadow in as many directions as desired, the direction-shadow size relationship being recorded.

In a modification with respect to the embodiment shown in Figure 1, the sensing head 19 can also sense raster marks of a capacitative or inductive nature. It is also possible to couple a synchro-type transmitter to the output shaft of the drive motor 7, in order to form signals corresponding to the angular position of the rotating holder 3 relative to the base-member 1.

The guide track 2 can alternatively be designed in a different manner, and can, for example, incorporate an extension of the rotating holder 3 in the form of a tubular flange which projects axially from the edge of those portions of the casing of the rotating holder 3 which form the boundary of the measuring field 15. The tubular extension can possess an opening, corresponding to the discontinuity in the guide track 2, in order to retain accessibility to the measuring field 15 from one side. Thus elongated, filamentary objects 22 can be brought into the measuring field 15 without an accessible end of the object 22 being available and which would have to be threaded if there were a ring-like arrangement.

If the filamentary object 22 leaves a production machine or a processing machine, for example an extruding machine, in a continuous forward-feed movement, care must be taken, in order to determine several diameter values or shadow sizes in different directions, to ensure that the rotating holder is very rapidly brought into the rotational position required at the instant in question, so that the measured and displayed diameter values, or shadow sizes, relate at least approximately to one and the same cross-section.

Should this be impossible in cases where the object to be measured is fed forward at high speeds, the apparatus illustrated in Figure 2 may be used. This apparatus incorporates a measuring system corresponding to the measuring system previously described and includes a laser 10, a rotating mirror 12, a mirror drive motor 13, a collimating lens 14, a convergent lens 16, and a detector 17. This system is fixed, or in a position which can be fixed in relation to a base-member of the apparatus not shown in Figure 2. As a result of their arrangement, the above-mentioned parts of this measuring system define a first scanning direction in relation to an object 22 the cross-section of which is to be measured.

In addition to the above-mentioned measuring system, a further two measuring systems are mounted at fixed positions relative to the base-member of the equipment, or in a manner permitting their positions to be fixed. The components of this system carry exactly the same reference numbers as those of the first-mentioned measuring system and in addition the reference letters a or b. These additional measuring systems define scanning directions relative to the object 22 which is to be inspected respectively subtending angles of 60° and 120° with respect to the scanning direction which is defined by the first measuring system. In certain cases, it can be advantageous if the scanning directions form angles of 90° and 135° with one another.

If the filamentary objects which are to be measured possess elliptical cross-sections, the determination of three shadow sizes, by means of scanning directions which subtend known angles, enables the largest and smallest diameters to be calculated, that is to say the principal axes of the ellipse, as well as to calculate their angular positions relative to a reference direction. These calculations are performed in suitable evaluating units.

While in Figure 2 individual lasers 10, 10a and 10b are assigned to the individual measuring

systems, the rays leaving the lasers 10a and 10b being directed, by means of the mirrors 25 and 26 respectively, onto the rotating mirror with which they are respectively associated, it is also possible to employ a single laser for transmitting light to all the rotating mirrors. For this purpose its output beam is supplied to the rotating mirrors via beam-splitting and reflecting devices. This arrangement is not shown in detail.

While in the case of the apparatus illustrated in Figure 2, the largest and smallest diameter values can be calculated from the measurements on one cross-section possessing a known and defined geometric shape, it is possible, in the case of the apparatus illustrated in Figure 1, to select the largest and the smallest measured values from a large number of measured values which are generated in the course of movement of the rotating holder 3 extending over 180°. For this purpose, the output signal from a comparator is used, in a manner known per se, for updating one register in the event of a subsequent measured value being larger than a preceding one, and for updating another register in the event of a measured value being smaller than a preceding one.

The measuring apparatus which have been described share the advantage that no separate devices are necessary for the purpose of manipulating the object which is to be measured, which devices could damage the surface of the object or which could restrict the accessibility of the measuring field, and which, if the object 2 is to be moved in the direction of its longitudinal axis, would have to be of comaratively complicated design. The individual measuring systems can be slightly staggered in the direction of the longitudinal axis of the object 22 if it is not absolutely necessary for the measured values to refer to one and the same cross-sectional plane.

CLAIMS

1. A method of measuring the cross-section of filamentary objects in which a focused beam of light is subjected to a parallel sideways displacement motion within a measuring field in which the object to be measured is positioned and the beam is detected after passage through the field except when obscured by the object so that the period of obscuration is a measure of the cross-section of the object in the direction of displacement of the beam wherein the displacement is carried out from a plurality of different orientations relative to the object.

2. Apparatus for carrying out the method as claimed in Claim 1 in which a rotating mirror and collimator provide the said parallel sideways displacement motion of the beam and optical focussing means serve to focus the beam after passage across the measuring field onto a detector, the said mirror, collimator, focussing means and detector being secured on a holder mounted to be rotatable around the object to be measured.

3. Apparatus as claimed in Claim 2 in which the holder is so designed that at least in one position thereof the measuring field is externally accessible to the object being measured.

4. Apparatus as claimed in Claim 3 in which a fixed guide of generally circular shape serves to support the rotatable holder, which guide extends over an angle of more than 180°.

5. Apparatus as claimed in Claim 4 in which drive means are provided for rotating the holder relative to the guide.

6. Apparatus as claimed in Claim 4 or Claim 5 in which an angle sensor is provided between the holder and the guide to determine the instantaneous angular position of the holder and thus enable idividual cross-sectional measurements to be correlated with particular orientations of the holder.

7. Apparatus as claimed in Claim 6 in which the angle sensor has a sensing head for sensing optical raster marks.

8. Apparatus as claimed in Claim 6 in which the angle sensor has a sensing head for sensing raster marks having capacitive or inductive properties.

9. Apparatus as claimed in any one of Claims 2 to 8 in which external connections to those components which are secured on the rotatable holder are taken through flexible cables.

10. Apparatus as claimed in any one of Claims 2 to 8 in which external connections to those components which are mounted on the rotatable holder are taken through a slip ring assembly mounted between the holder and its base support.

11. Apparatus for carrying out the method as claimed in Claim 1 and comprising a plurality of optical systems each at a different fixed orientation relative to the cross-section of an object being measured, each system having a rotating mirror and collimator to provide the parallel sideways displacement motion of the beam, optical focussing means to focus the beam after passage across the measuring field and a detector for the focussed beam.

12. Apparatus as claimed in Claim 11 in which the output signals from the respective detectors and signals indicating the speed of rotation of the respective rotating mirrors are all evaluated simultaneously.

13. Apparatus as claimed in Claim 11 or Claim 12 in which three measuring systems are provided the output signals from which are fed to a common arithmetic unit.

14. Apparatus as claimed in any one of Claims 2 to 13 in which evaluating circuits are provided for determining the maximum and minimum diameters of the cross-section of an object being measured.

15. Apparatus for measuring the cross-section of filamentary objects substantially as described with reference to Figure 1 or Figure 2 of the accompanying drawings.

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